#35242449

FISH DISTRIBUTION AND LIMNOLOGICAL CONDITIONS UNDER ICE COVER IN ANCHOR BAY, LAKE ST. CLAIR, 1979

Michael T. Werner

Bruce A. Manny

ADMINISTRATIVE REPORT

December 1979

Prepared for the U.S. Army Corps of Engineers, Great Lakes and St. Lawrence Seaway, Navigation Season Extension Demonstration program, January-April 1979.

Great Lakes Fishery Laboratory

U.S. Fish and Wildlife Service

1451 Green Road

Ann Arbor, Michigan 48105

Blank Pages in the Original Document Have Been Omitted.

EXECUTIVE SUMMARY

1. In response to requests received from the Michigan Department of Natural Resources and the U.S. Army Corps of Engineers (COE) in July-August 1978, the U.S. Fish and Wildlife Service's Great Lakes Fishery Laboratory undertook a COE-funded study of winter fish distributions and limnological conditions in the Anchor Bay-St. Clair Flats area of Lake St. Clair, during January-April 1979. The overall objective of the study was to provide baseline data needed for a preliminary evaluation of the potential adverse effects, if any, of the Navigation Season Extension Program proposed by the COE.

2. Fish and limnological information was collected at 1-2 week intervals January 30-April 5, 1979, at four stations in shallow (2 m) waters around the western and northern margin of Anchor Bay; at eight stations in secondary river channels in St. Clair Flats; and on April 5, 1979, at four stations in deeper (3-4 m) waters near the center of Anchor Bay.

3. Nineteen species of fish were taken during the study in gillnets (mesh sizes ranging from 1- to 5-in mesh, stretched measure) and in small (3 ft x 3 ft x 5 ft) traps covered with 1/4-in hardware cloth. Gizzard shad were 52% of the catch; yellow perch 22%; trout-perch, northern pike, spottail shiner, and emerald shiner made up 21% of the catch; and 12 other species made up the remainder.

4. Catches during the period of ice cover differed from those made immediately after ice cover broke up; 11 species of fish were present in catches made during the period of ice cover and 15 were present in catches immediately after the breakup of ice cover. Gizzard shad was the most abundant species during ice cover (65% of the under-ice catch) but was absent from catches made after ice cover broke up. Yellow perch was the second most abundant fish taken under ice (16% of the catch) and the most abundant fish taken after ice breakup (45% of the catch). Changes in the abundance of gizzard shad and yellow perch during the study are consistent with the available information on their seasonal distribution in Great Lakes waters.

5. Ice cover in nearshore areas of Anchor Bay was 33-40 cm by the end of January, reached a maximum of 42-45 cm at the end of February, and broke up by the end of March; the deeper, open waters of the bay had little or no ice cover, as did the channel highways (secondary river channels) in the St. Clair Flats area.

6. Water temperatures under ice cover in the nearshore waters of Anchor Bay were low (0.0-1.0°C) throughout the water column from January 30-March 6, 1979; rose to 0.4-1.7°C by March 14; and reached 3.5-4.5°C by April 5 after ice-out. Water temperatures in the channel highways were also low (0.0-1.0°C) from February 12-March 6, 1979. Open waters of the Bay were colder (2°C) than shallower, nearshore waters along the margin

of the Bay (3.5-4.5°C) on April 5, 1979. Inverse temperature stratification beneath ice cover was not found at any of our stations.

7. Measurements of water currents showed water about 10 cm beneath the ice at four stations around the western and northern margin of Anchor Bay circulated at the rate of 1.6-2.5 cm sec^{-1} in a counterclockwise direction and parallel with shore.

8. Turbidity was generally very low; i.e., < 2 nephelometric turbudity units (NTU), at all stations January 30-March 1, 1979. During March, in Anchor Bay, turbidity increased steadily beneath ice cover to intermediate levels (7-10 NTU) and abruptly to high (50 NTU) levels at one station off the mouth of the Salt River. In the channel highways of St. Clair Flats, turbidity remained low (0.7-2.1 NTU) until March 1, increased briefly on March 6-7 (3.0-15.3 NTU), then returned to low levels (1.5-4.0 NTU). Turbidity values in the deeper, offshore waters of Anchor Bay were much lower (2.0-4.5 NTU) than in shallow waters around the margin of Anchor Bay (7.5-14.4 NTU) on April 5, 1979.

9. Light penetration to 1 m in the nearshore waters of Anchor Bay (stations 1-4) was reduced 60-90% when and where snow and ice cover was present.

10. Dissolved oxygen concentrations in the nearshore waters of Anchor Bay were high during ice cover (9.8-16.4 mg/l) and after ice breakup (12.4-13.3 mg/l). Concentrations of dissolved oxygen at all our sampling stations were adequate to support fish of all kinds throughout the winter.

11. Concentrations of dissolved oil and grease just beneath ice cover were very low (0.23-0.53 mg/l) in channels of the St. Clair River and around the margin of Anchor Bay before ice-out and in the latter area just after ice-out. However, our limited sampling effort may have prevented us from obtaining baseline values that are representative of the Anchor Bay-St. Clair Flats area as a whole.

INTRODUCTION

In response to requests received from the Michigan Department of Natural Resources (MDNR) and the U.S. Army Corps of Engineers (COE) in July-August 1978, the U.S. Fish and Wildlife Service's Great Lakes Fishery Laboratory (GLFL) undertook a COE-funded study of winter fish distributions and limnological conditions in the Anchor Bay-St. Clair Flats area of Lake St. Clair, during January-April 1979. The overall objective of the study was to provide baseline data needed for a preliminary evaluation of potential adverse effects, if any, of the Navigation Season Extension Program (NSEP) proposed by the COE. The Anchor Bay-St. Clair Flats area was selected for study because it is considered by many to be an ecologically sensitive area and is adjacent to and receives inflow from the St. Clair River, a major navigation route included in the NSEP.

Specific objectives for the study were to describe under-ice distribution and abundance of fish, the baseline limnological conditions under ice, and the potential for under-ice movement of vessel spills of oil and related substances that could be hazardous to fish in the study area. The concern over oil spills arose because over 15 million tons of refined petroleum products, including 3.4 million tons of fuel oil are shipped each year by lake carrier through the Great Lakes (U.S. Army Corps of Engineers 1977); large quantities of this fuel oil are shipped down the St. Clair River during the period of ice cover (A.G. Ballard, pers. comm.); and shipments of petroleum products, including fuel oil, down the St. Clair River would probably increase during the period of ice cover, if the NSEP is implemented.

MATERIAL AND METHODS

THE STUDY AREA

The study area encompassed that section of Anchor Bay and the St. Clair Flats northeast of a line drawn from the southwest corner of Harsen's Island to the mouth of the Clinton River (Fig. 1). Because of the generally acknowledged, unstable ice conditions in the study area that made over-ice travel unsafe in many locations, access to the sampling stations was to have been provided by the Detroit District Corps of Engineers' airboat. However, mechanical problems with the airboat precluded its use for this study and necessitated several changes in the planned frequency of sampling and in the locations to be sampled. The sampling stations that were finally selected are shown in Figure 1 and listed (with coordinates) in Appendix 1. Stations 1-4 were selected to represent the shallow nearshore waters of Anchor Bay. Stations 5-12 were selected to represent the "channel highways"--those secondary river channels that carry large volumes of water from the main channels of the St. Clair River (where the most direct impacts of winter navigation could occur) and distribute that water to Anchor Bay and to the smaller, productive embayments in the St. Clair Flats area. Stations 13-16 were

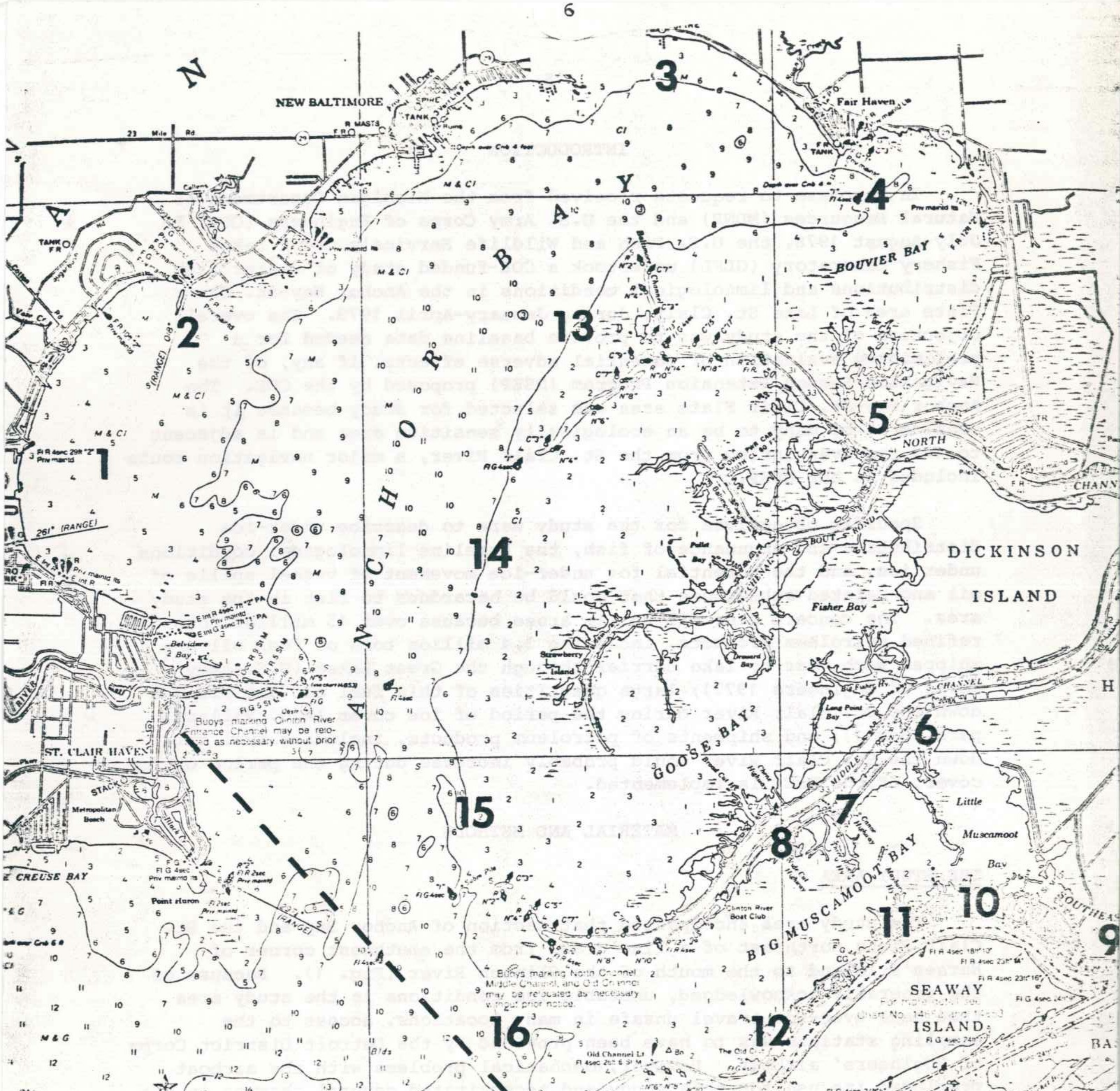

Figure 1. Sampling stations in the Anchor Bay-St. Clair Flats area of Lake St. Clair.

chosen to represent the deeper waters of Anchor Bay which receive the direct inflow from the North Channel of the St. Clair River.

We began the field work on January 20, 1979, when ice at stations 1-4 became thick enough (10 cm) to support the field party traveling on foot. Stations 1-12 were visited weekly as ice and weather conditions permitted, through the week of March 6, 1979, (the last week of safe ice at stations 1-4). Sampling at stations 5-12 was conducted from docks or from bridges spanning these channels. Stations 1-4 and 13-16 were visited by boat on April 4-5, 1979, as soon after ice-out as boat travel was safe.

FISH METHODS

Fish were sampled with 140-ft experimental gillnets; each net consisted of seven 20-ft panels, each of a different mesh size (1-, 1-1/2-, 2-, 2 1/2-, 3-, 4-, and 5-in mesh, stretched measure). Gillnets were set along the depth contours during daylight and retrieved during daylight on the following day.

Gillnets were set under the ice as follows: a line of holes was drilled in the ice at 12-ft intervals for about 320 ft using a gasoline powered ice auger and an ice spud. A line was passed under the ice from one hole to the next using a wooden dowel rod, 16-ft long. The gillnet was then attached to the line and pulled under the ice. When the gillnet was completely under the ice, anchors were tied on, the net was stretched to its full length, markers were attached, and the net was lowered to the bottom. When a net was retrieved, a weighted line was left beneath the ice to facilitate setting the net on the next visit to the station.

In January, only one 140-ft net was fished at each station; because of the low catches in January, we set two 140-ft nets during each visit to each station in February-April (Table 1; Appendix 2). A total of four 140-ft gillnet sets were made under the ice at stations 1-4 in January; 30 under-ice sets (two 140-ft nets per station per visit) were made at stations 1-4 in February-March; and 16 sets (two 140-ft nets per station per visit) were made by boat at stations 1-4 and 13-16 in April. Deterioration of the ice cover at station 2 prevented us from setting gillnets there on March 6.

Fish were also sampled with hardware cloth funnel traps. These traps were constructed of 1/4-in hardware cloth and were 3 ft high, 3 ft wide, and 5 ft long. Both ends of each trap were fitted with a square 3 ft x 3 ft hardware cloth funnel that tapered to a 4 1/2-in square opening into the trap. The traps were fished overnight adjacent to the gillnets at stations 1-4; at stations 5-12, the traps were set with their long axes parallel to the flow of water.

Table 1. Sampling effort for fish and limnological information by location and date, January 30-April 5, 1979. [G = 280 ft of experimental gillnet; T = hardware cloth trap; L = limnological measurement; O = oil and grease.]

	DATES							
Station	1/30	2/6	2/13	2/29	3/6	3/14	3/28	4/5
1	G*,L,O	G,L,O	G,T,L,O	G,L^+	G,L,O	L,O	L,O	G,L
2	G*,L,O	G,L^+,O	G,T,L,O	G,L	L,O	L	L,O	G,L
3	G*,L,O	G,L,O	G,T,L,O	G,L^+	G,L^+,O	L,O	L,O	G,L
4	G*,L,O	G,L,O	G,T,L,O	G,L	G,L^+,O	L,O	L,O	G,L
5		O	T,L,O	L	T,L,O	L,O	L	
6		O	O	O,L	T,L,O	L,O	L	
7				T,L	T,L	L		
8				L	T,L	L		
9		O	O	L,O	T,L,O	L,O	L	
10				T,L	T,L	L		
11				T,L	T,L	L		
12				L^+	T,L	L		
13								G,L
14								G,L
15								G,L
16								G,L

*Only 140 ft of gillnet fished.

+Includes water current measurements.

Four trap sets were made at stations 1-4 in February, but their use at these stations was thereafter discontinued because they caught no fish. The traps were more effective at stations 5-12, and a total of 12 sets was made at those stations in February-March (Table 1; Appendix 2).

Fish taken in the gillnets and traps were identified, measured (total length in mm), and weighed (g). Whenever possible, fish were returned to the water alive.

LIMNOLOGICAL METHODS

Limnological information and data on levels of dissolved oil and grease were collected weekly at stations 1-12 as ice conditions permitted (Table 1; Appendix 4). Under-ice sampling was accomplished by cutting a hole ≥20 cm in diameter through the ice with an ice auger and spud. A perforated scoop, previously rinsed in freon and transported into the field in a sealed plastic bag, was used to dip ice chips out of the hole. Water for oil and grease analysis was then collected as follows: wearing plastic gloves, previously rinsed with freon, we removed glass prescription bottles, 1 liter in volume, from individual, sealed plastic bags in which they were transported into the field; filled them from 5-10 cm below the water surface; sealed them with aluminum-lined caps; and placed them in an insulated container to protect the water from freezing. Within 8 hours, these water samples were preserved with 5 ml of 12N H_2SO_4 and refrigerated until they were analyzed in the laboratory (usually within 3-5 days). Two 1-liter water samples for analysis of turbidity, conductivity, dissolved organic matter, and suspended particulate matter were then collected from 5-10 cm below the water surface in a plastic bottle and placed in an insulated container to prevent the samples from freezing. After each day in the field, these water samples were refrigerated until they were analyzed in the laboratory (usually within 3-5 days). Measurements throughout the water column were then made of light penetration using a 4 π submersible photometer (Protomatic Model 1, Protomatic Co., Dexter, MI)[1/]. This photometer measured incident light in the range of 300-800 nm with peak sensitivity at 560 nm and was calibrated in foot-candles. Snow and ice chips on top of the ice surrounding the hole were not cleared away until after light readings were made. Water temperature and dissolved oxygen concentrations were measured throughout the water column with a thermistor-dissolved oxygen meter (YSI Model 54, YSI Co., Yellow Springs, OH). The thermistor-oxygen meter was calibrated weekly against a stem thermometer and oxygen measurements made using the azide modification of the Winkler method (APHA 1976). Snow and ice cover were measured with a meter stick. Secchi disc measurements were made with a standard white Secchi disc, 20 cm in diameter.

1/ Use of trade names or manufacturer's names does not imply Government endorsement of any commercial product.

Initial attempts to measure water currents at station 2 just beneath the ice with a mechanical current meter (Gurley, Model 622, W.L. Lawrence and Co., Baltimore, MD) showed currents were present but were below the limit of detection (about 10 cm sec^{-1}) for that instrument. To measure these slow currents, we developed a systematic procedure for determining the speed and direction of movement of small droplets of dye released just below the under surface of the ice. The dye was released from a 1-m length of 5 mm (O.D.) glass tubing, the mouth of which was fire-polished to an internal diameter of slightly less than 1 mm. The release of small droplets of dye was facilitated by attaching a 5 ml plastic BD syringe to the upper end of the dye-release tube with a short piece of tubing. The dye we used was a saturated solution of green, water-soluble dye (Fluorescein, Matheson, Coleman, and Bell; Cincinnati, OH). This solution did not freeze at temperatures of about -10°C and, although a little heavier than water, its rate of sinking in water was so slow (about 1 cm min^{-1}) that when a droplet of this solution was released in still water, the dye remained suspended as a brilliant green marker. Field measurements were made as follows: a standard white Secchi disc, 20 cm in diameter, was suspended 20 cm below the underside of the ice, and the line from the disc was attached to a support spanning the hole on top of the ice. Five minutes were then allowed for currents beneath the ice to return to normal. We then drew up 0.1-0.2 ml of dye into the dye-release tube; removed with a tissue paper any dye adhering to the exterior of the tube; and slowly inserted the tube in the water alongside the line attached to the Secchi disc. After carefully positioning the mouth of the tube about 10 cm above the center of the Secchi disc, we then slowly depressed the plunger of the syringe until a droplet of dye was released. We then measured with a stop watch the time required for the droplet to drift horizontally to the edge of the disc (10 cm) and, by reference to a compass, we also determined the direction of movement. Several such measurements were made in succession over a period of several minutes and the measurements were then averaged and recorded.

In the laboratory, refrigerated water samples were warmed to room temperature (20-23°C) before analysis. Turbidity was measured in nephelometric turbidity units (NTU) with a nephelometric turbidimeter (HF Turbidimeter, Model DRT 1000) as given in Standard Methods (APHA 1976). Because of its greater precision, sensitivity, and applicability over a wide range of turbidity, the nephelometric method, calibrated against standard reference suspensions of Formazin polymer, is the recommended standard method (APHA 1976) and the one we selected. For comparison, we also included measurements of suspended particulate matter and Secchi disc depth, which have been used by others as expressions of turbidity (Chandler 1942; Beeton 1958). Suspended particulate matter was measured by filtration at 15 psi onto a preweighed glass-fiber filter (Reeve Angel 984H, 0.3 μm porosity). Dissolved organic matter was measured by absorption of UV light (Beckman Spectrophotometer, Model 25) and fluorescence (Turner Fluorometer, Model 110) after Wetzel and Otsuki (1974) as follows: absorption of ultraviolet light at 250 nm and fluorescence of filtered water was measured in 1-cm quartz cells at room temperature. Excitation of fluorescence was by ultraviolet light of 360 nm which passed through a filter (Turner, No. 811) before falling on the sample. Fluorescence by the sample at 460 nm passed through two secondary filters (Turner, Nos. 816 and 831) and was recorded at 30X range in relative units. Specific conductance was measured with a conductance meter (YSI Conductivity Bridge, Model 31). Analysis of oil and grease followed the Partition Infrared Method (tentative) outlined in Standard Methods (APHA 1976) except that readings were made in matched, 1-cm, quartz cells at the peak absorbance of number 2 fuel oil in freon (272 nm) on a UV-visible, double beam spectrophotometer (Beckman, Model 25) rather than at 2930/cm wavenumber on an IR spectrophotometer. Number 2 fuel oil was used as the reference standard because it is the petroleum product shipped in largest quantity aboard carriers on the Great Lakes (A.G. Ballard, pers. comm.) and thus would be the type of oil most likely to be released into the environment as a result of an accidental spill. In separate tests, the Beckman instrument at 273 nm was shown to be equivalent in sensitivity to a double-beam, infrared spectrophotometer at 2930/cm (Perkin-Elmer, Model 467) for measuring the absorbance of freon extracts of oil and grease in natural waters by reference to standards of number 2 fuel oil.

RESULTS AND DISCUSSION

FISH

Fish Distribution and Abundance

Gillnets and traps fished January 30-April 5 in Anchor Bay and the St. Clair Flats area caught 555 fish of 19 species (Table 2; Appendix 2). Gizzard shad made up 52% of the catch, and yellow perch 22%; trout-perch, northern pike, spottail shiner, and emerald shiner collectively made up 21% of the catch, and 12 other species made up the remaining 5%.

The 19 species we collected during the study represent about 25% of those reported for the lake and include most of the common species that would be vulnerable to the sampling gear we used (Appendix 3). Not represented in the catches were generally: (1) the smaller species that could not be caught effectively in the smallest mesh gillnets we used; (2) species that characteristically are not captured in small traps, such as those we used; (3) species that are rarely observed in the lake; and (4) species that may have been of low abundance at or absent from the sites we sampled during January 30-April 5.

Comparison of gillnet catches for January 30-March 6 during ice cover, with those of April 4-5 after ice cover broke up, suggests the species composition and relative abundance of fishes in the shallow waters of Anchor Bay differed during the two periods. Of the 18 species captured in gillnets (Table 2), 11 were represented in gillnet catches made during the period of ice cover and 15 were present in gillnet catches made after ice-out (Appendix 2); gizzard shad and alewives were

Period	Size Class (mm)*				
	100-139	140-179	180-219	220-259	260-299
Under ice	15	50	3	0	0
After ice breakup	12	19	2	8	8

*Size classes after Jobes, 1952.

The absence of yellow perch, with lengths greater than 200 mm, in our catches in the shallow nearshore waters of Anchor Bay during the period of ice cover are in agreement with reports of angler success we obtained during conversations with ice fishermen on Lake St. Clair, and consistent with unpublished findings that adult yellow perch (age group II and older; larger than about 200 mm) are uncommon in shallow nearshore waters in Lake Michigan in the winter (L. Wells, pers. comm).

Areal differences in the abundance of some species is suggested by the gillnet catches. More gizzard shad and yellow perch were usually caught at station 4 than at stations 1-3 (Table 3; Appendix 2). No satisfactory explanation can be offered for the higher abundance of gizzard shad and yellow perch at station 4. Gillnet catches of muskellunge were made almost exclusively at station 2 (Appendix 2). According to R. Haas, MDNR (pers. comm.), the area represented by station 2 may be a pre-spawning, staging area for muskellunge. The brindled madtom, Noturus miurus, was an incidental catch at stations 1 and 2; several hundred of these fishes were present in the large masses of Myriophyllum and Elodea retrieved with the gillnets at those stations on April 4-5. Such concentrations of this non-abundant species have not been previously recorded for Lake St. Clair.

Little discussion of fish distribution and abundance based on our trap catches is possible. No fish were caught in the traps at stations 1-4 in the nearshore waters of Anchor Bay, and only rainbow smelt, one common white sucker, one rock bass, one trout-perch, and one sea lamprey were taken at stations in the channel highways (Appendix 3). The mudpuppy salamander, Necturus maculosus, was an unexpected catch in the traps in both Anchor Bay and the channel highways (Appendix 3).

In summary, the present study suggests that fewer species of fish were present in the shallow, nearshore areas under ice than during the ice-free period of the year. Our catches under ice were primarily gizzard shad and yellow perch. After ice-out, we caught no gizzard shad, but catches of yellow perch increased. The yellow perch captured after ice-out were also noticeably larger than those taken under ice, and many exhibited signs of spawning readiness. Further description of the bathymetric distribution of fish under ice in Anchor Bay and the St. Clair Flats area is difficult because the unavailability of an airboat prevented us from sampling the deep, offshore waters (stations 13-16) throughout the winter as originally planned. Our attempts to sample the deep, offshore waters by boat immediately after ice-out were also frustrated when strong lake currents loaded the gillnets set at stations 13-16 on April 4 with plant detritus (primarily remnants of last year's growth of Myriophyllum and Elodea) and moved two of the nets about a mile from where we had set them. Thus, although the seasonal differences described above may, in fact, reflect changes in the areal or bathymetric distribution of certain Lake St. Clair fishes, we are unable to demonstrate this conclusively with the available information.

LIMNOLOGY

Ice thickness in the nearshore areas of Anchor Bay (Stations 1-4) had reached 33-40 cm when we began our field sampling on January 30, 1979 (Appendix 4). Ice thickness increased gradually in the nearshore waters of Anchor Bay during February to a seasonal maximum of 42-45 cm on February 28, declined during March, and disappeared entirely by March 28. Maximum ice thickness (50 cm) in the entire study area was measured in one of the channel highways (station 8) on February 26, 1979. Several of the channel highways in St. Clair Flats (stations 7, 9, 10, and 11), and the deeper waters near the center of Anchor Bay did not develop ice cover during the winter.

Snow cover on the ice was 2-8 cm and relatively complete, January 30-February 4, 1979, along the western and northern shorelines of Anchor Bay (stations 1-4), but was absent in all areas by February 26, 1979 (Appendix 4).

Water temperatures under ice cover in the nearshore waters of Anchor Bay (stations 1-4) were 0.0-1.0°C throughout the water column from January 30-March 6, 1979, rose to 0.4-1.7°C by March 14, and reached 3.5-4.5°C by April 5 (Appendix 4). Water temperatures in the channel highways (stations 5-12) were 0.0-1.0°C from February 12 through March 6. Open waters of the Bay (stations 13-16), sampled once on April 5, were colder (2°C) than shallower nearshore waters (stations 1-4) along the margins of the Bay (3.5-4.5°C) on that date. Inverse temperature stratification, observed beneath ice cover in Canadian waters of Lake St. Clair by Wallen (1977) was not found at any of our stations.

The speed and direction of water currents, measured infrequently in the nearshore waters of Anchor Bay (stations 1-4) showed water about 10 cm beneath the ice circulated at the rate of 1.6-2.5 cm sec^{-1} (Appendix 4). All our current measurements fell near the lower end of the range (0.2-46.0 cm sec^{-1}) reported under conditions of partial ice cover for Lake Michigan (Malone 1968), Lake Huron (Saylor and Miller 1976), and Lake Erie (Palmer and Izatt 1972). The direction of the current in Anchor Bay (stations 1-4) was counterclockwise and parallel with shore.

Turbidity was generally very low (< 2 NTU) at all stations January 30-March 1, 1979, (Appendix 4). After March 1, in Anchor Bay, turbidity increased steadily beneath ice cover to intermediate levels (7-10 NTU) at stations 1, 3, and 4, and abruptly to high (50 NTU) levels at station 2 (Appendix 4) as a result of spring runoff from the Salt River (GLFL, unpubl. data). After ice-out, turbidity continued to increase at stations 1 and 3. Highest turbidity (22 NTU) at station 4 was found just after ice-out. In the channel highways (stations 5-12) turbidity remained low (0.7-2.1 NTU) until March 1, increased briefly on March 6-7 at stations 5, 6, and 9 (3.0-15.3 NTU), then returned to low levels (1.5-4.0 NTU) for the remainder of March. During the ice-free season, turbidity levels in the North, Middle, and South Channels of the St. Clair River were very constant and fell in the range of 0.3-3.0 NTU (GLFL, unpubl. data). Turbidity values in the deeper, offshore waters of Anchor Bay (stations 13-16) were much lower (2.0-4.5 NTU) than around the shallower waters of Anchor Bay (stations 1-4; 7.5-14.4 NTU) on April 5, the one date when all eight stations were visited concurrently. Turbidity values in the open waters of Anchor Bay during the ice-free season (in 1977 and 1978) usually fell in the range of 3-8 NTU (GLFL, unpubl. data).

Secchi disc measurements (depths) generally varied inversely with turbidity values measured by the nephelometric method. Secchi disc depths under ice were high; and the disc could usually be seen on the bottom in 2-3 m of water (Appendix 4). Secchi disc depths were greater in the open waters of Anchor Bay, (stations 13-16) after ice-out (range: 160-200 cm) than in the shallow nearshore waters of the bay (stations 1-4; range: 30-90 cm) on the one occasion (April 5) when the two areas were visited on the same day.

Temporal and spatial trends in suspended particulate matter values (Appendix 4) followed closely those of nephelometric turbidity values discussed above. Suspended particulate matter values were highly correlated with nephelometric turbidity values in the nearshore waters of Anchor Bay (stations 1-4; $r = 0.90$; $N = 20$) and in the channel highways (stations 5-12; $r = 0.95$; $N = 14$). Throughout our study values of suspended particulate matter ranged from 0.1 mg l^{-1} at station 3 on February 6-7, 1979, to 47.3 mg l^{-1} at station 2 on March 6-7, 1979.

Dissolved organic matter, measured as fluorescence at 460 nm and absorption of UV light at 250 nm, was much lower under ice cover in the nearshore waters of Anchor Bay (stations 1-4; 4-27 units of fluorescence and 0.016-0.053 units of absorption of UV light) than after ice-out (13-43 units of fluorescence, and 0.039-0.083 units of UV absorption; Appendix 4). Highest concentrations of dissolved organic matter were found under ice cover on March 6 and 14 off the mouth of the Salt River (station 2) at the time of spring runoff.

Specific conductance was relatively uniform under ice cover (217-240 μmho/cm @ 25°C) during January and February in the nearshore waters of Anchor Bay (stations 1-4), but decreased to 63-193 μmho/cm beneath the ice cover at stations 1, 3, and 4 and to 200-218 μmho/cm in the channel highways at stations 5, 6, and 9 following snow melt on February 26 (Appendix 4). In late March, as ice cover deteriorated and spring runoff began, conductance at stations 1 and 2 increased sharply to 322-338 μmho/cm, while conductance at the other stations returned to the range of 217-240 μmho/cm observed under ice cover. By April 5, conductance at station 2 also returned to the range of 217-240 μmho/cm, but remained high at stations 1 and 4 (259 and 258 mho/cm respectively). On April 5, conductance in the open waters of Anchor Bay (stations 13-16) was lower and less variable (212-219 μmho/cm) than in the nearshore waters (stations 1-4; 234-259 μmho/cm).

Light penetration to 1 m in the nearshore waters of Anchor Bay (stations 1-4) was reduced 60-90% when and where snow and ice cover was present (Appendix 4). By February 26, snow cover had melted and light penetration through the ice increased. Highest light penetration was found at stations 2-4 in late February and early March after snow cover disappeared. After ice-out, light penetration at stations 1-4 varied inversely with turbidity, and at station 2, with dissolved organic matter. The percentages of incident light penetrating through snow and ice cover at stations 1-4 (1-52%) agreed closely with similar values (3-41%) obtained by Wallen (1977) under the ice at nearshore stations in Canadian water of Lake St. Clair. Light penetration to 1 m in the channel highways was reduced by 60-92% by snow and ice cover at stations 5, 6, 8, and 12 in February and by 20-90% at stations 5-12 in March by concentrations of suspended particulate matter > 3 mg/l (Appendix 4).

Dissolved oxygen concentrations in the nearshore waters of Anchor Bay (stations 1-4) were high during ice cover (9.8-16.4 mg/l) and after (12.4-13.3 mg/l) ice breakup (Appendix 4). Equipment failure prevented measurements of dissolved oxygen in the channel highways (stations 5-12) in March and in the offshore waters of Anchor Bay (stations 13-16) in April. Percent saturation values of oxygen at all stations were high (69-113%; most values were between 80% and 90%) during and after the period of ice cover. Oxygen supersaturation was found at stations 1-4 on February 12-14 just before snow cover disappeared. The lowest saturation value was measured at the bottom of the water column off the mouth of the Salt River (station 2) on March 14 when large amounts of suspended particulate matter and dissolved organic matter were entering the lake under ice cover from the river. Data contained in this report show concentrations of dissolved oxygen at all of our sampling stations were adequate to support fish of all kinds throughout the winter.

Measured values of dissolved oil and grease under the ice in Anchor Bay and St. Clair Flats varied from 0.5 mg/l (the limit of detection) to 10.4 mg/l (Appendix 4). Values for samples collected prior to March 14, 1979, were not reliable because oil concentrations in some water samples and freon extracts deteriorated before analyses were completed, and because contamination introduced during sample collection and analysis caused some high values. These two problems were corrected as soon as we became aware of them. During the weeks of March 14 and 28, water samples were collected without contamination and analyzed promptly, and we believe values for oil and grease on these dates are reliable. The data for March 14 and 23, although few in number, are the first such data for the Great Lakes. They suggest (see below) dissolved oil and grease concentrations were very low just before ice-out in Anchor Bay at stations 1-4 and in the channels of the St. Clair River at stations 5, 6, and 9, on March 14 and 28. However, unequivocal interpretation of our results is difficult, because the behavior of oil under ice is complex (see Deslauriers 1978). Current velocities we measured under ice in Anchor Bay at stations 1-4 (1.6-2.5 cm sec^{-1}) were less than the minimum required to move number 2 fuel under ice (3.5 cm sec^{-1}; Uzuner and Weiskopf 1975) suggesting that even if oil reached Anchor Bay from the St. Clair River during the period of ice cover, it would have been trapped beneath the ice in the bay before it reached stations 1-4. The low levels of dissolved oil and grease measured in the channel highways at stations 5, 6, and 9 may have been a reflection of the lack of ice cover and the high water velocities at those stations, which would have prevented oil accumulation at those stations and made detection of an oil spill difficult.

Concentrations of dissolved oil and grease (mg/l) just before and just after ice-out in Anchor Bay and St. Clair Flats, Lake St. Clair, March 1979.

	Station Number						
Date	1	2	3	4	5	6	9
March 14	0.39	*	0.39	0.23	0.52	0.53	0.43
	0.36		0.30	0.29			
March 28	0.24	0.44	0.19	0.05	**	**	**
	0.15						

*Sample lost to breakage during storage.
**Ice conditions prevented sample collection.

In summary, our limnological measurements demonstrate that water temperatures, water current velocities, and turbidity remained low during the period of ice cover (January-March 1979) at our sampling stations in Anchor Bay and St. Clair Flats, and provide an accurate description of baseline winter conditions in this portion of Lake St. Clair. Our data also show other environmental conditions in the lake changed within the study area during the winter. For example, ice and snow cover reduced light penetration to very low levels (< 10% of incident light penetrated to 1 m) during most of the winter. Strong water currents prevented ice cover from forming over most of the channel highways in St. Clair Flats and over much of the deeper waters in the center of Anchor Bay during the winter of 1979; however, water currents along the lake margin just beneath ice cover were very weak. As spring approached, snow cover disappeared and ice thickness decreased causing a drop in specific conductance beneath ice cover and allowing more light to penetrate through the ice. The additional solar radiation caused water temperatures to begin rising slightly beneath ice cover, particularly near the bottom of the water column at the shallow, nearshore stations. Water quality beneath ice cover began to degrade in the spring just prior to ice-out along the western and northern shorelines due to increased quantities of suspended particulate matter and dissolved organic matter added to the lake by tributaries along these developed shorelines. The lowest value of dissolved oxygen saturation (69%) was found at this time off the mouth of the Salt River where these impacts were greatest. Elevated levels of turbidity (3.4-15.3 NTU) and suspended particulate matter (5.8-19.8 mg/l) were also found on March 6-7, 1979, in the North, Middle, and South Channels of the St. Clair River before ice-out in Anchor Bay. The particulate and dissolved organic matter inputs reduced Secchi disc depth and light penetration markedly in Anchor Bay and, owing to the increased absorption and scattering of insolar radiation, accelerated the rise in water temperatures that brought about the loss of ice cover in the bay. After ice-out, shallow nearshore waters of Anchor Bay warmed more rapidly than water near the center of the bay and in channels of the St. Clair River.

Our measurements of dissolved oil and grease immediately before and after ice breakup in Lake St. Clair suggest present "baseline" levels of those materials were low in the shallow, nearshore waters of the northwestern portion of Anchor Bay and in the channel highways in the St. Clair Flats. However, our limited data, coupled with the complex behavior of oil in an ice environment, may have prevented us from obtaining baseline values that are representative of the Anchor Bay-St. Clair Flats area as a whole.

ACKNOWLEDGMENTS

Thomas A. Edsall and Thomas P. Poe provided valuable counsel in the preparation of the manuscript. The field and laboratory work would have been impossible without the help of Joseph Bruce, Melinda Mott, James Denier, and Alexander deBausset. Additional assistance in the limnological analyses was provided by Dale Christensen.

LITERATURE CITED

American Public Health Association et al. 1976. Standard methods for the examination of water and waste water. 14th ed., American Public Health Association, New York.

Beeton, A.M. 1958. Relationship between Secchi disc readings and light penetrations in Lake Huron. Trans. Am. Fish. Soc. 87:73-79.

Caroots, M.S. 1976. A study of the gizzard shad, Dorosoma cepedianum (LeSueur), from Lake Erie near Cleveland, Ohio. Unpub. M.S. Thesis. John Carroll University. 128 pp.

Chandler, D.C. 1942. Limnological studies of western Lake Erie. II. Light penetration and its relation to turbidity. Ecology 23:41-52.

Deslauriers, P.S. 1978. Oil spill behavior in ice during the 1977 Buzzards Bay oil spill. Pages 198-215 in Proc. Conf. on Assessment of Ecological Impacts of Oil Spills, Amer. Inst. Biol. Sci., 14-17 June 1978, Keystone, Colorado.

Edsall, T.A. and T.G. Yocom. 1972. Review of recent technical information concerning the adverse effects of once-through cooling on Lake Michigan. U.S. Fish. Wild. Serv., Great Lakes Fishery Laboratory, Ann Arbor, Michigan. 86 pp.

Goodyear, C.D. 1978. Evaluation of 316(b) Demonstration: Detroit Edison's Monroe Power Plant. Great Lakes Area Office, Office of Ecological Services. U.S. Fish. Wild. Serv., Great Lakes Fishery Laboratory, Ann Arbor, Michigan. 245 pp.

Hatcher, C.O. 1977. Evaluation of environmental impact data, Saginaw Bay waste heat demonstration program. U.S. Fish. Wild. Serv., Great Lakes Fishery Laboratory, Ann Arbor, Michigan. 120 pp.

Jobes, F.W. 1952. Age, growth, and production of yellow perch in Lake Erie. U.S. Fish. Wild. Serv. Fish. Bull. 52:205-266.

Malone, F.D. 1968. An analysis of current measurements in Lake Michigan. J. Geophys. Res. 73:7065-7081.

Palmer, M.H. and J.B. Izatt. 1972. Lake movements with partial ice cover. Limnol. Oceanogr. 17:403-409.

Saylor, J.H. and G.S. Miller. 1976. Winter currents in Lake Huron. NOAA Tech. Memo. ERL, GLERL-15, Great Lakes Environ. Res. Lab., Ann Arbor, Michigan.

U.S. Army Corps of Engineers. 1977. Waterborne Commerce of the United States. Part 3, 1977. U.S. COE, Chicago District.

Uzuner, M.S. and F.B. Weiskopf. 1978. Transport of oil slick under a uniform smooth ice cover. Draft report prepared for Office of Research and Development, U.S. Environmental Protection Agency, Washington, DC.

Wallen, D.G. 1977. Production processes under the ice in Lake St. Clair. I. Irradiation and Temperature. Water Resources Bulletin. 13(2):299-307.

Wells, L. 1968. Seasonal depth distribution of fish in southeastern Lake Michigan. U.S. Fish. Wild. Serv. Fish. Bull. 67(1):1-15.

Wetzel, R.G. and A. Otsuki. 1974. Allocthonous organic carbon of a marl lake. Arch. Hydrobiol. 73(1):31-36.